Melting of massive ice 'lid' resulted in huge release of CO2 at the end of the ice age

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Credit: Jenny Roberts

A new study reconstructing conditions at the end of the last ice age suggests that as the Antarctic sea ice melted, massive amounts of carbon dioxide that had been trapped in the ocean were released into the atmosphere.

The study includes the first detailed reconstruction of the Southern Ocean density of the period and identified how it changed as the Earth warmed. It suggests a massive reorganisation of ocean temperature and salinity, but finds that this was not the driver of increased concentration of carbon dioxide in the atmosphere. The study, led by researchers from the University of Cambridge, is published in the journal *Proceedings of the National Academy of Sciences*.

The ocean is made up of different layers of varying densities and chemical compositions. During the last ice age, it was thought that the deepest part of the ocean was made up of very salty, dense water, which was capable of trapping a lot of CO2. Scientists believed that a decrease in the density of this deep water resulted in the release of CO2 from the deep ocean to the atmosphere.

However, the new findings suggest that although a decrease in the density of the deep ocean did occur, it happened much later than the rise in atmospheric CO2, suggesting that other mechanisms must be responsible for the release of CO2 from the oceans at the end of the last ice age.

"We set out to test the idea that a decrease in ocean density resulted in a

rise in CO_2 by reconstructing how it changed across time periods when the Earth was warming," said the paper's lead author Jenny Roberts, a PhD student in Cambridge's Department of Earth Sciences who is also a member of the British Antarctic Survey. "However what we found was not what we were expecting to see."

In order to determine how the oceans have changed over time and to identify what might have caused the massive release of CO_2, the researchers studied the chemical composition of microscopic shelled animals that have been buried deep in ocean sediment since the end of the ice age. Like layers of snow, the shells of these tiny animals, known as foraminifera, contain clues about what the ocean was like while they were alive, allowing the researchers to reconstruct how the ocean changed as the ice age was ending.

They found that during the cold glacial periods, the deepest water was significantly denser than it is today. However, what was unexpected was the timing of the reduction in the deep ocean density, which happened some 5,000 years after the initial increase in CO_2, meaning that the density decrease couldn't be responsible for releasing CO_2 to the atmosphere.

"Before this study there were these two observations, the first was that glacial deep water was really salty and dense, and the second that it also contained a lot of CO_2, and the community put two and two together and said these two observations must be linked," said Roberts. "But it was only through doing our study, and looking at the change in both density and CO_2 across the deglaciation, that we found they actually weren't linked. This surprised us all."

Through examination of the shells, the researchers found that changes in CO_2 and density are not nearly as tightly linked as previously thought, suggesting something else must be causing CO_2 to be released from the

ocean.

Like a bottle of wine with a cork, sea ice can prevent CO2-rich water from releasing its CO2 to the atmosphere. The Southern Ocean is a key area of exchange of CO2 between the ocean and atmosphere. The expansion of sea ice during the last ice age acted as a 'lid' on the Southern Ocean, preventing CO2 from escaping. The researchers suggest that the retreat of this sea ice lid at the end of the last ice age uncorked this vintage CO2, resulting in an increase in carbon dioxide in the atmosphere.

"Although conditions at the end of the last ice age were very different to today, this study highlights the importance that dynamic features such as sea ice have on regulating the climate system, and emphasises the need for improved understanding and prediction as we head into our ever warming world," said Roberts.

More information: Evolution of South Atlantic density and chemical stratification across the last deglaciation, *PNAS*, www.pnas.org/cgi/doi/10.1073/pnas.1511252113

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